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PHOTOHELIOGRAPH THERMAL VACUUM
OPTICAL TEST CHAMBER

August 12, 1968

R. Hahn

Approved by: _____

A handwritten signature in black ink, reading "J. Denton Allen". The signature is written in a cursive style with a large, looped initial "J".

J. Denton Allen, Task Leader,
Photoheliograph Task

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FOREWORD

This report covers work on one phase of the photoheliograph development task, NASA Code 945-84-00-01-00, for the period November 1967 through June 1968. The photoheliograph has been proposed to NASA for the Apollo telescope mount (ATM) by Caltech, with Professor Harold Zirin as the principal investigator and Dr. Robert Howard of Mt. Wilson and Palomar Observatories the co-investigator (see TM 33-369, November 1967). The objective of the investigation is to obtain high resolution cinematographs in white light near ultraviolet and narrow band hydrogen alpha. Because of the ATM program uncertainties, emphasis has been placed on areas of technology that are somewhat mission-independent, but the ATM spacecraft has been used to establish design constraints.

SUMMARY

A test chamber has been designed for testing of the ATM-photoheliograph. Performance of the optical system and the temperature control system will be verified while subjecting the telescope to a simulated equatorial orbit solar input with appropriate S/C interfaces simulated.

The chamber provides solar simulation, S/C interface simulation and vacuum. The optical test technique is interferometric, calculating telescope modulation transfer functions from measured optical path differences. The telescope design criteria is for less than one-twentieth wave optical path difference for any two rays forming the image; therefore the chamber will be seismically isolated to minimize induced vibration and resultant extraneous optical path differences due to vibratory displacement.

The implementation of the design specifications for this test chamber are state-of-the-art. The combination of all the environmental parameters into a single test chamber does not presently exist, to our best knowledge. The manufacturer of the Interferometer uses the instrument successfully, in a similar test chamber, but does not have the capability of providing solar radiation.

PHOTOHELIOGRAPH THERMAL VACUUM
OPTICAL TEST CHAMBER
CHAMBER DESIGN REQUIREMENTS

The test chamber described herein, will provide a thermal vacuum environment with solar radiation for performing optical system and temperature control system tests of the photoheliograph. The vacuum requirement is twofold: eliminate the effects of heat transfer by conduction and convection from the test results, and eliminate distortion of the optical path length caused by air. The thermal requirement is also twofold: simulate the S/C boundary conditions of the telescope and simulate the solar thermal input. Another requirement for this test chamber is vibration isolation. This is necessary to reduce the seismic and man-made vibrations such that the relative motions of the optical elements are comparable to their design tolerances (twentieth wave) and we can therefore verify that design tolerances were achieved and are maintained in test.

The test instrument to be used is a laser unequal path interferometer (LUPI). This instrument will be used as in a two-pass autocollimating configuration. In this configuration the laser beam is introduced into the telescope at the image plane and emerges from the entrance as a collimated beam. This is reflected from a return flat back in the direction of actual solar energy flow. This beam emerges from the image plane and re-enters the LUPI, where an interferogram is produced. This configuration will magnify the optical path errors by a factor of four. The LUPI must be located outside of the vacuum tank with an optical window provided for transferring energy through the tank wall, because it requires adjustment during use and because the interferogram is formed inside the LUPI. For the short duration while the interferogram is being recorded, the solar beam and pumping will be interrupted in order to provide better resolution of the interferogram. The upper surface of the return flat is 1° off normal to the telescope axis, so that it won't send a return

beam back through the telescope; for the same reason, windows between the chamber and solar source are also tipped.

Two classifications of tests will be performed in the test chamber. The first consists of the primary mirror only, in its support. As it is the energy-gathering device its thermal optical properties are very critical. The second classification of tests consists of the entire optical system, with the exception of the filters and cameras, in its assembled configurations. There are many other types of tests that could be performed in this chamber, however, presently only these two have been defined.

The design requirements of the test chamber are:

1. Vacuum. A pressure level of 1×10^{-4} torr or less. This is sufficient to reduce the conduction and convection losses to essentially zero and reduce the optical distortion to an acceptable value for the laser use. Valving is such that pumps can be stopped while the interferogram is formed. A very important consideration of the vacuum environment is contamination by foreign materials. Since there are exposed optical surfaces present and optical testing of extreme accuracy is being done, deposition of any material on these optical surfaces must be avoided. Hence, cold-trapping is required.
2. Solar radiation. One solar constant (133 watts/ft.^2) at the primary mirror surface, with characteristics as close to the actual sun as possible.
3. Thermal. To provide a simulated spacecraft interface at its appropriate temperature. The ATM main spar is to be maintained at $+70^\circ\text{F}$ and the canister is to be maintained at $+50^\circ\text{F}$.
4. Vibration. As low a vibration environment that will produce a stable interferogram. A numerical value of 2×10^{-4} inches per second (at any frequency) has been established, based on the experience of the Itek Company facility; they form satisfactory interferograms in such a test environment. Effort is currently continuing to evolve a requirement based on our design, by use of twentieth wave relative displacement criteria and dynamic analysis of telescope/facility structure.

CHAMBER DESCRIPTION (Fig. 1)

We plan to implement these requirements in the test chamber in the following manner:

1. Vacuum. A Roots type pump was selected as it has the lowest backstreaming of any pump that meets the requirements of pumping speed and operating pressure range. A mechanical backing pump is also required for initial roughing down and then backing the Roots when it begins operation. A liquid nitrogen cooled trap will also be used to insure that no oil vapor can enter the chamber from the pump and also act as a collector for any residual water vapor.

2. Solar radiation. The system is basically the same as is used in the 10 and 25-ft Space Simulators at JPL except the beam diameter is only 3-ft. Many of the components were made available to us from another project which was not completed. A 20 KW xenon arc lamp will be used as the energy source, instead of the original 5 KW xenon lamp, to provide the required one solar constant at the primary mirror. Our system has been analyzed using a computer program developed for the large space simulators, and the results show that our system will have a collimation angle of $\pm 1^\circ$ and a uniformity of intensity across the beam of ± 6 percent.

3. Thermal. Temperature controlled shrouds surrounding the photoheliograph will provide the simulated S/C interface. Due to the lack of detailed information of the exact configuration of the spacecraft and thermal requirements we have not proceeded with the detailed design of the thermal control system.

4. Vibration. A pneumatic vibration isolation system will be used to isolate the test chamber from the building. All attachments, with the exception of instrumentation wiring, will be disconnected from the chamber during interferometer testing. The Solar Simulation System will not be attached to the test chamber but will irradiate the Photoheliograph through a fused silica window. The test chamber will be rigidly mounted to an inertia mass of concrete below it, and this assembly will then be supported on the vibration isolators. The inertial mass lowers the center of gravity of the test chamber/mass so that attaching the isolators at the center of gravity of the combination minimizes the susceptibility of the assembly to rocking motion.

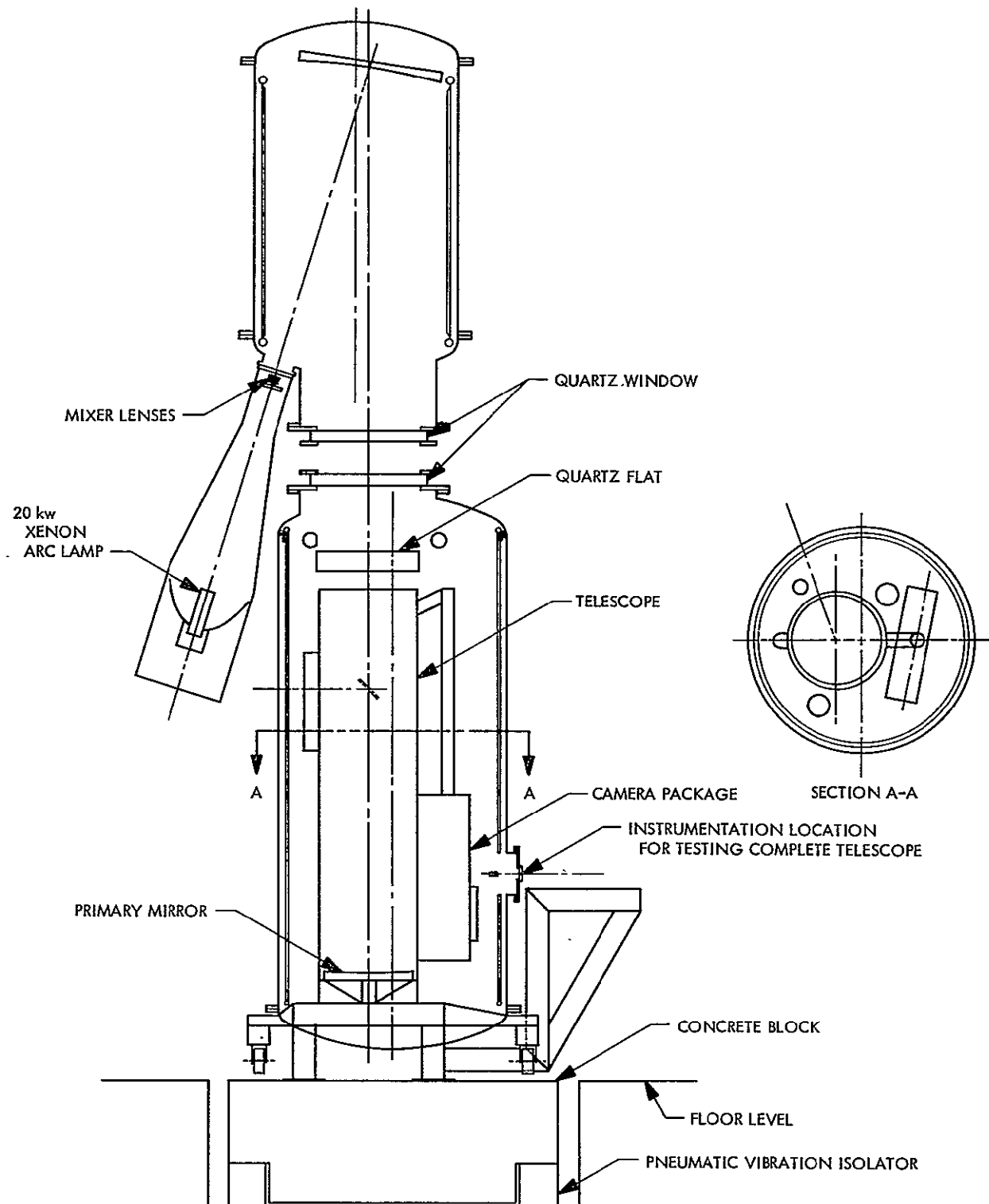


Figure 1. Photoheliograph Test Chamber

The following instrumentation will be provided:

1. Pressure. Continuous pressure measurement below 1 torr using a hot filament ionization gauge.
2. Contamination. Continuous measurement of deposited mass on a cooled quartz crystal. This crystal is in an oscillator circuit whose frequency is determined by the mass of the crystal. As deposition occurs, the change in frequency is recorded, with a variation in the rate of change being an abnormal condition.
3. Solar radiation intensity. A solar cell will be located in the test chamber which can be remotely positioned to a repeatable location to read the intensity of the beam during a test.
4. Solar radiation uniformity. A solar cell will be mounted so it can be remotely positioned in the beam at various locations and obtain intensity vs. location prior to installation of the test item.
5. Temperature. Provision will be made for bringing sufficient thermocouple leads out of the tank to measure the required temperatures of all the appropriate components.
6. Vibration. We have available to use, on a loan basis, a single-axis seismometer, which has been used to measure the vibrations in various candidate buildings for housing the test chamber. If experience dictates, a permanent installation will be made.

The test chamber, as it has been described here, actually consists of two chambers, one above the other. For vibration isolation reasons the two chambers will not be in physical contact. The solar simulation system is a source of many vibrations which would create an impossible situation for interferometer testing, were everything contained in a single chamber. The upper chamber and a pumping system for it exists, as part of the equipment made available to us. The vacuum level is not critical, the reasons for evacuating are to prevent the formation of ozone which would degrade the collimating mirror and to reduce heating due to any absorption. As there are two fused silica windows with a pressure differential across each for the solar energy to pass from one chamber to the other, an implosion shield will be provided as a matter of safety. The upper chamber and all its necessary auxiliaries, which

are attached, will be moveable to provide clearance for raising the lower tank shell during photoheliograph installation or modification. The lower chamber will house the photoheliograph and provide the thermal vacuum environment. This chamber will contain an internal structure to which all the optical components, including the photoheliograph, but excluding the LUPI, will be attached. This structure, in turn will be rigidly mounted to the inertia mass. The tank shell surrounding this structure will not be used as a structural member for supporting any of the optical components. This will eliminate any deflections due to pressure load experienced in pumping down from atmosphere to vacuum. It will also permit the alignment of the complete optical system prior to lowering the tank shell. The LUPI will be mounted on its own structure, external to the tank shell, also rigidly attached to the inertia mass. Provision will be made for some remote adjustments of the optical elements to compensate for thermal expansion should this be experienced during the test. Provision will also be made for testing the optical components individually in their actual position on the structure.

All necessary auxiliary equipment for operation of the test chamber will be provided i. e., a 5 ton capacity bridge crane, handling fixtures, lifting slings, etc. A central operating console will be provided from which all the equipment can be operated and monitored. Included in this console will be all the required safety devices for safe and proper operation of the test chamber.

The solar simulation system optics are presently being set up and tested in the laboratory to prove that their performance matches the results of the computer analysis. By varying some of the parameters, the specifications stated previously can hopefully be improved. Preliminary inspection with the aid of the computer yielded results encouraging enough to proceed with the testing.